Original Article

A Two-level Model of Motor Performance Ability

Lena Lämmle[1], Susanne Tittlbach[2], Jennifer Oberger[3], Annette Worth[4], Klaus Bös[3]

[1]*Department of Sports Psychology, Technische Universität München, Munich, GERMANY*
[2]*Institute of Sports Science, University of Bayreuth, Bayreuth, GERMANY*
[3]*Institute of Sport and Sports Science, University of Karlsruhe, Karlsruhe, GERMANY*
[4]*University of Education Schwäbisch Gmünd, Schwäbisch Gmünd, GERMANY*

For many years, motor performance ability (MPA) has been viewed as a multidimensional construct consisting of such specific components as endurance, strength, coordination, and flexibility. This report examines whether these assumed structures of MPA can be found empirically in children and adolescents. The Motoric-Module, conducted between 2003 and 2006 in Germany for the differentiated measurement of MPA from ages 6 to 17 ($N = 2{,}840$), made use of an eight-item performance test battery. This test battery was assumed to assess the five motor dimensions of endurance, strength, coordination under time pressure, coordination under precision demands and flexibility. A two-level model of MPA with these five motor dimensions as first order factors could be confirmed using confirmatory factor analysis. The path coefficient ($p < 0.001$) describing the direct effect from MPA to strength was 0.97, followed by the effect from MPA to coordination under precision demands (a = 0.73). The coefficient relating from MPA to coordination under time pressure was less (a = 0.64) and the lowest loadings shown for MPA are demonstrated for endurance (a = 0.36) and flexibility (a = 0.23). The first order factors showed significant direct effects on each of the observed variables. Therefore, a differentiated diagnosis of MPA in children and adolescents is possible. This is important for health care. [*J Exerc Sci Fit* • Vol 8 • No 1 • 41–49 • 2010]

Keywords: children and adolescents, motor dimensions, motor performance ability

Introduction

The level of motor performance ability (MPA) in children and adolescents has been discussed intensively during the past few years and also in the framework of health promotion. Thus, in studies analyzing the health status of children and adolescents, MPA measures are often integrated (e.g. Kretschmer & Wirszing 2007; Fu et al. 2004; Bös 2003). Recent studies often used different assessment methods of MPA so that different dimensions of MPA are considered (Nagasaki et al. 1995; Bös & Mechling 1983). As a consequence, results cannot easily be compared. To be able to supply general and comparable information about MPA of children and adolescents, the dimensions of MPA must be clearly defined.

There exists a multiplicity of work concerning the dimensionality of MPA with most of the analyses performed between 1950 and 1980 (e.g. Corbin 1991; Bös & Mechling 1985; Bös & Mechling 1983; Cratty 1979; Powell et al. 1978; Fleishman 1954). Most of these approaches assume that MPA is a complex, multidimensional construct, which cannot be described adequately using only one parameter, as is often desired by professionals using test batteries (schools, etc.). However, most of the authors use different subdimensions of MPA. A frequently used and ordinary differentiation is based on conditioning and coordinative aspects (Bös & Mechling 1983). Further systematizations differentiate between health-related physical fitness (Nagasaki et al. 1995), as for example cardiovascular endurance, muscular strength and endurance, balance and flexibility,

Corresponding Author
Lena Lämmle, Department of Sports Psychology, Technische Universität München, Conollystrasse 32, 80809 Munich, GERMANY.
E-mail: laemmle@sp.tum.de

ELSEVIER

and skill development (Corbin 1991), and skill-related fitness (Hands & Larkin 2006), as for example manual speed, agility or speed, respectively. In addition, it became obvious that the dimensionality of MPA is not the same for different target groups. Fleishman and Quaintance (1984), for example, analyzed the dimensionality of young men mainly from the armed forces. Their systematization used strength, flexibility, gross body coordination, gross body equilibrium and stamina as fundamental motor abilities, whereas Nagasaki et al. (1995) confirmed strength, walking, balance, flexibility, stamina and manual speed as fundamental motor abilities in men and women over 60 years of age.

The database of recent dimensionality analyses were primarily made up of young adult males. The first analyses were performed using young men (e.g. Fleishman & Quaintance 1984; Fleishman 1954). Test batteries based on these structure models of MPA are often used (e.g. Graf et al. 2008; Nagasaki et al. 1995). However, evidence for a structural model for physical fitness has only been published for older adults during the last decades (Nagasaki et al. 1995; Greene et al. 1993) and has led to a changed dimensionality of MPA for older adults. Nevertheless, the testing of motor fitness is very common nowadays and the once found dimensionality of MPA has simply been adapted to children. There has been no attempt to investigate whether the confirmed dimensions of MPA for adults can be equally used for children and adolescents. Since children and adolescents have different movement actions, the confirmed models for adults cannot be easily transformed to children and adolescents without empirical proof.

Thus, the aim of this paper is to fill this research gap while (1) finding a valid differentiation of MPA for children and adolescents and (2) examining if MPA is a complexly determined multidimensional construct.

Differentiation of MPA

The most famous theoretical differentiation of MPA for children and adolescents in Germany is the three-level model of Bös (1987) (Figure 1). It differentiates MPA into conditioning (energetically-determined) and coordinative (information-oriented) abilities on the second level. The first level consists of the basic abilities of endurance, strength, speed, coordination and flexibility.

Describing these basic abilities, 10 subdimensions were extracted. The conditioning abilities of strength and endurance are differentiated due to duration and intensity of workload into aerobic (AE) and anaerobic endurance (AnE), as well as maximum strength (MS), speed strength (SS) and muscular endurance (ME) (Hollmann & Hettinger 2000). MS and SS are mainly determined by muscular (number of fibers, fiber cross-section, fiber structure) and neurophysiologic (recruiting and rate coding of motor characteristics) conditions (Bührle & Schmidtbleicher 1981). Action velocity (AV), as the sport-specific occurrence of speed, cannot clearly be assigned to the conditioning or coordinative ability dimension. In contrast to AV, the speed of response seems to be a

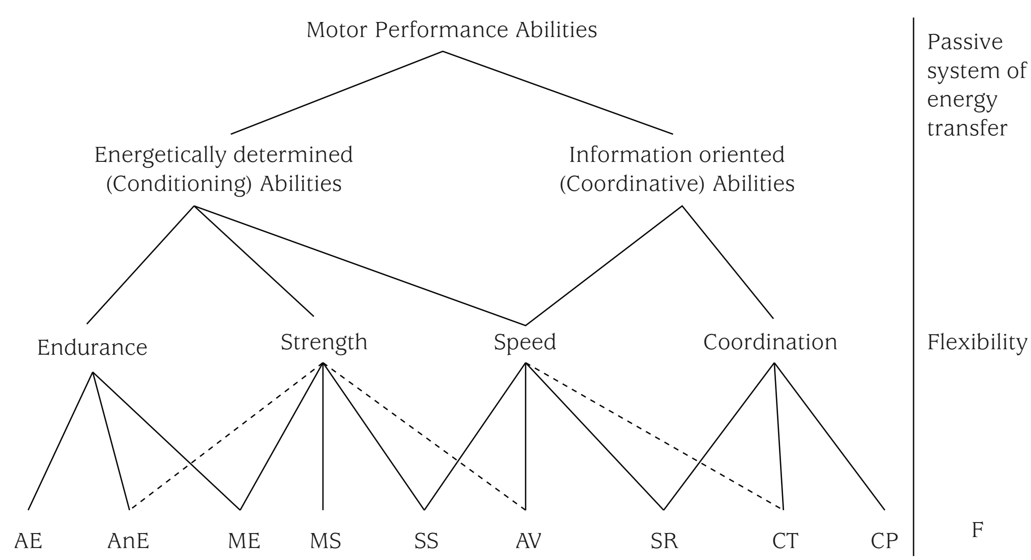

Fig. 1 Differentiation of motor abilities (Bös 1987, p. 94). AE = aerobic endurance; AnE = anaerobic endurance; ME = muscular endurance; MS = maximum strength; SS = speed strength; AV = action velocity; SR = speed of response; CT = coordination under time pressure; CP = coordination with precision requirement; F = flexibility.

relatively self-contained motor ability. The systematization of coordination is much more difficult than that of the conditioning abilities. This is due to the fact that the associations between the level of processes and products are not already sufficiently known. Coordination is a very complex ability and several different differentiations of coordination exist (e.g. Roth 1982; Hirtz 1977). One possibility for differentiation is due to the kind of sensory regulation, on the one hand, and dependent on the task profile of the movement, on the other hand. Roth (1982) has used inductive approaches (Hirtz 1977) as well as dimension-analytical approaches and distinguished between the two areas of coordination under time pressure and coordination under precision demands. This means that coordination is understood in performing fast and/or precise body movements. Bös (1987) has used this differentiation of coordination. For further differentiation, whole body movements and body segment movements could be distinguished on a next level. In this differentiation, coordination under precision demands includes balance tasks and coordination under time pressure includes agility tests, amongst others. Flexibility cannot clearly be assigned to conditioning or coordinative abilities. In this differentiation, flexibility is not seen as ability, but rather as an anatomically determined personal performance prerequisite of the passive systems of energy transfer (Bös & Mechling 1983).

Since this differentiation was established, several theoretical considerations and empirical analyses have been carried out showing us the need to modify the model of Bös (1987) as follows (Figure 2).

First of all, there is no distinction between conditioning and coordinative factors on the second level, as it is made in the theoretical, hierarchical model of Bös (1987). On the one hand, this is due to the fact that with regard to the underlying research questions, the focus is on describing the entirety of MPA rather than analyzing the hierarchy of MPA. On the other hand, it does not seem to be reasonable to describe MPA based on two levels with latent constructs from a statistical point of view. For this reason, and moreover in accordance with other authors (Nagasaki et al. 1995), a two-level model of MPA with the latent constructs of cardiovascular endurance, strength, coordination under time pressure, coordination under precision demands and flexibility is considered.

Secondly, statistical analyses (Bös & Mechling 1983) have shown that cardiovascular endurance, coordination under precision demands and MS represent basic motor abilities, which are statistically independent, whereas coordination under time pressure, speed and

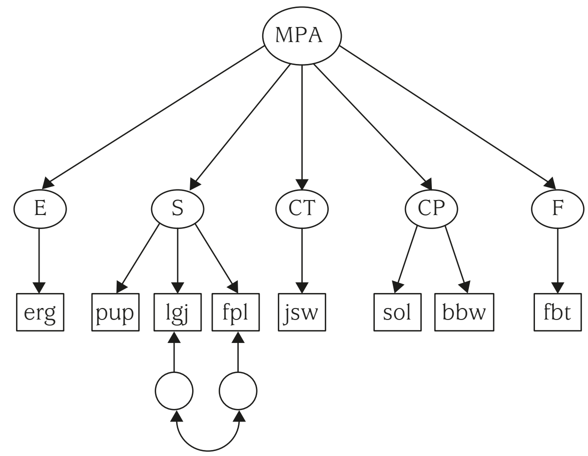

Fig. 2 A two-level model of motor performance ability. MPA = motor performance ability; E = endurance; S = strength; CT = coordination under time pressure; CP = coordination with precision requirement; F = flexibility; erg = bicycle endurance test; pup = push-ups; lgj = long jump; fpl = force plate; jsw = jumping sideways; sol = standing on one leg; bbw = balancing backwards; fbt = forward bending of the trunk.

ME represent complexly determined motor abilities. This emphasizes the need to separate coordination under precision demands and coordination under time pressure already on the first level, since no association could be found statistically. Coordination under precision demands is not associated with other abilities, whereas coordination under time pressure is associated with SS (see also Roth 1982).

Thirdly, speed is not considered a motor ability in the present model. Schmidtbleicher (1980) has empirically shown that AV is a complexly determined ability and not a basic dimension. It is always associated with strength and coordination under time pressure (Bös 2003). Therefore, only these two dimensions are considered in the present model.

This theoretically and empirically based model used for differentiation of MPA in children and adolescents is the basis for examining the two research questions in the present paper.

Methods

Sample and study

The following analyses are based on data retrieved during the Motoric-Module (MoMo) as part of the German Health Interview and Examination Survey for Children and Adolescents (KiGGS), which was conducted between May 2003 and May 2006. The KiGGS survey is a nationwide, cross-sectional study on the health status of children and adolescents from ages 6 to 17, conducted by the Robert Koch Institute of Berlin (Kamtsiuris et al. 2007; Kurth 2007). The KiGGS survey was complemented by the MoMo for a more differentiated recording of physical activity and MPA (Bös, Worth, Opper et al. 2009).

The MoMo test battery was administered in its entirety to 2,840 children and juveniles (1,404 girls, 1,436 boys) with an average age of 11.45 ± 3.37 years (range, 6–17 years). Participation was voluntary. Participants were randomly chosen nationwide using registration offices of 167 German places of study.

Motor tests

Participants were tested with eight tests to assess a complete motor fitness profile involving endurance, strength, coordination under precision demands, coordination under time pressure and flexibility (see Table 1; Bös et al. 2004; Bös 2001). The test battery was designed to be easily used in small rooms for physical examination. The content-related validity of all tests was evaluated as being good throughout with regard to significance and feasibility as based on expert ratings. More precisely, the test development was based on an international expert questionnaire involving 40 selected fitness experts in 25 European countries who were asked about the relevance of the test contents and requirements in sport-motoric tests regarding the documentation of MPA (Bös 1992). Subsequently, 13 experts evaluated the significance and practicability of the study exercises on a scale of 1 (very good) to 5 (very bad). The evaluations in both regions were found to be within a good range ($M_{Significance} = 1.9$; $M_{Practicability} = 1.7$). To determine test–retest reliability, the motoric tests were performed twice within 4 days on the same children, applying the same test situation and the same study investigator. All in all, there were good test–retest reliability coefficients ($r_{min} = 0.74$ to $r_{max} = 0.96$).

Endurance

A bicycle ergometer test was used for gathering information on the aerobic fitness performance and consequently also on the cardiovascular system. The test starts with a calculated initial load of $0.5\,W \cdot kg^{-1}$ body weight. This is then followed by an increase in load of a further $0.5\,W \cdot kg^{-1}$ body weight every 2 minutes. The test is then discontinued for any one of the following three reasons: (1) when a load heart rate of 190 (6–10 years) or 180 (11–17 years) beats $\cdot\, min^{-1}$ is observed; (2) when the frequency of rotation decreases below 50 revolutions $\cdot\, min^{-1}$ for a period of at least 20 seconds; (3) when the subject stops due to exhaustion. The variable used for analysis is the wattage associated with a heart rate of 170 divided by the body weight (relative PWC 170). Since the health-related MPA should be assessed, PWC 170 and not the maximum heart rate load has been chosen as an endurance criterion. Additionally, PWC 170 is an internationally comparable endurance criterion (Hollmann & Hettinger 2000).

Strength

The tests used to measure strength were the standing long jump, force plate for high jumps and push-ups.

Table 1. Taxonomy of tests by ability and pattern of expenditure

Task structure	Motor performance ability					Passive systems of transfer of energy
	Aerobic endurance	Strength	Speed	Coordination		Flexibility
	AE	ME SS	CT	CT	CP	F
Locomotion motion						
Going					bbw	
Bounds		lgj; fpl		jsw		
Gross motor skill partial body movement						
Upper body		pup				fbt
Lower body	erg					
Bearing						
Entire body					sol	

AE = aerobic endurance; ME = muscular endurance; SS = speed strength; CT = coordination under time pressure; CP = coordination with precision requirement; F = flexibility; bbw = balancing backwards; lgj = long jump; fpl = force plate; jsw = jumping sideways; pup = push-ups; fbt = forward bending of the trunk; erg = bicycle endurance test; sol = standing on one leg.

The standing long jump is an aid for measuring the jumping power and springiness of the leg muscles. The task to be performed by the test subject is to jump as far as possible using both legs together. The subject stands with their legs parallel and with bent knees on the starting line. One is allowed to increase the propulsion only by swinging one's arms. The jump is performed using both legs and by landing on both feet, while one is not permitted to grasp backwards with one or both hands. The distance from the starting line to the heel of the foot furthest back after landing is measured (in cm). The best of two jumps was used for analysis.

The force plate serves to measure the capability of the leg extenders for demonstrating springiness. The subject stands in place on the measurement plate while keeping his/her hands positioned on the hips. No additional propulsion is to be achieved by using the arms. The subject must obtain his/her propulsion from the standing position only by bending their legs. The test participants are supposed to jump upwards in a vertical direction as high as possible and land again on the platform. The power-time history of the reaction strength on the force plate is measured and evaluated with the help of a computer employing an analog/digital converter. The height jumped in meters is then computed as an important parameter. The variable used for analysis was the best out of three attempts. Between each of the three high jumps, there was a rest of 30 seconds each.

Standing long jump and high jump on a force plate serve to measure the SS in both cases. With the aid of the force plate, a practice-oriented test as well as an apparatus-supported test should be employed in order to describe the SS. Practice-oriented tests benefit from the practicability and apparatus-supported tests are more precise. Thus, the aim of using both tests is to enable comparisons to both tests in prospective studies. If the analyses carried out show that force plate and standing long jump measure similar aspects of SS, the force plate will be removed from the test battery in order to have an easily feasible test battery.

Push-ups serve to measure the dynamic ME in the upper extremities. The test participants had to perform as many push-ups as possible within 40 seconds. The number of correctly performed push-ups is counted. The test subject lies in a prone position on his/her stomach and the hands grasp one another on the buttocks. The hands are released from behind the back, placed beside the shoulders, which are then pressed towards the floor until the arms are extended and the body leaves the ground. Subsequently, one hand is released from the ground and claps onto the other hand. During this process, only the hands and the feet have contact with the ground. The trunk and the legs are extended. A lordosis should be avoided. Afterwards, the arms are kept flexed toward the body while still in a prone position and the initial position is assumed once again. Before a new push-up is performed, the test subject must grasp his/her hands behind their back. From this position, the push-ups are counted. The variable used for analysis was the number of correctly performed push-ups in 40 seconds. The 40 seconds are oriented to validated and standardized values in Germany (Bös & Tittlbach 2002) as well as internationally (Suni 2000). This involves either 30 or 40 seconds. In order to accentuate the ME, 40 seconds was selected.

The MoMo test battery contains no measurements of the MS. Firstly, this is due to a high risk of injuries when applying MS tests to children or juveniles. A young body cannot easily sustain high mechanical loads compared to an adult body. Damage due to overloads can occur (Weineck 2007). Secondly, MS can only be measured with the help of apparatus-supported tests and several body segments (arms, legs, and trunk) must be tested. Since the MoMo test battery should be a practical test battery, none of these apparatus-supported tests for assessing MS was included.

Coordination under time pressure

Jumping sideways is used to measure total body coordination under time pressure, speed and the ME capabilities of the lower extremities.

Over the course of 15 seconds, the test participants must jump with both legs at the same time, as quickly as possible, sideways over the middle line of a carpet mat. Two 15-second sets are performed with a 1-minute break between the two phases. The 15 seconds are oriented, for reasons of comparison, on the well-known and recognized coordination test of Kiphard and Schilling (1974). Evaluated is the number of jumps made over the course of the two sets. The variable used for analysis was the mean value of the two attempts at jumping from side to side.

Coordination under precision demands

Tests measuring coordination under precision demands are standing on one leg and balancing backwards (Kiphard & Schilling 1974). Both of these tests are measures of coordination for the entire body.

Standing on one leg serves for evaluating sensomotoric regulation while performing an exercise involving precision. The task for the test subject is to stand on one leg, chosen by him/herself, on a T-shaped balancing bar for 1 minute. If the free foot touches the ground, the test subject must try to immediately recapture the balancing position on the T-bar. The timer continues to run during this short contact with the ground. However, if one completely leaves the bar, the timer is stopped until the subject is able to resume the same initial position. The person is not allowed to change the standing leg during the test. The objective is to avoid touching the ground for as long as possible. The arms can be used to aid balance. The number of contacts made with the ground is counted. The variable used for analysis was the number of ground contacts of the leg being held up during the 1 minute.

Balancing, while walking backwards, also serves to evaluate coordination under precision demands. The test participants must walk backwards and keep their balance on three different-sized beams. The test always begins from a start platform. The widths of the beams are 3, 4.5 and 6 cm and they are each 300 cm long. The goal is to stay on each of the beams during the course of two valid attempts. A total of six successful attempts are evaluated. The number of steps made while walking backwards is counted. The variable used for analysis was the sum of steps made over all six attempts while walking backwards.

Flexibility

The forward bending of the trunk is used to measure flexibility. This is used to measure the flexibility of the trunk and the elasticity of the back and leg muscles. The subject stands on a wooden box and slowly bends forward at the waist. The arms and hands must reach as far as possible downward. Hereby, the legs must remain extended. The maximum position of bending is held for 2 seconds. The better of two attempts is recorded in centimeters.

Model

As already described in the introduction, MPA was extracted as a second order factor based on the five first order factors of endurance, strength, coordination under time pressure, coordination under precision demands and flexibility (Figure 2). Hereby, from a theoretical and statistical point of view, all of these first order factors must be understood analogous to that described by Bös (1987) (see the Introduction section). Endurance, coordination under time pressure and flexibility are only described by one variable. Coordination under precision demands was derived from two indicators, namely standing on one leg and balancing backwards. Strength was composed of three indicators (push-ups, long jump, and force plate). Since jumping on a force plate and the standing long jump represent speed of strength as subdimensions, these two items have been correlated in the analysis.

Statistical analysis

Confirmatory factor analysis was conducted with AMOS 16.0 (SPSS Inc., Chicago, IL, USA) using maximum likelihood measures. All measurements were controlled for sex and age. The assumption of multivariate normality could not be confirmed by the Mardia test (multivariate kurtosis = 7.256; c.r. = 15.284; $p < 0.001$). Therefore, a Bollen-Stine bootstrap procedure (200 samples) was conducted in order to obtain a corrected p value for the χ^2 test.

In addition to the χ^2 test, we also used fit indices for model evaluation. The assessment of the global goodness-of-fit was based on the standardized root mean square residual (SRMR), the root mean squared error of approximation (RMSEA), as recommended by Hu and Bentler (1999) and, additionally, on the Comparative Fit Index (CFI), as recommended by Beauducel and Wittmann (2005). According to Hu and Bentler (1999), cut-off values of about RMSEA ≤ 0.06, SRMR ≤ 0.11 and CFI ≥ 0.95 are appropriate.

In order to specify a model containing latent variables for all functional factors, error variances were set at zero and loadings were set at 1 for functional factors with only one manifest variable.

Residuals from subtests assigned to the content category were allowed to covary, as indicated by corresponding arrows in the path diagram.

Besides confirmatory factor analysis, descriptive statistics and correlations for not normally distributed data (Spearman-Rho) were calculated using SPSS 16.0 (SPSS Inc.).

Results

Descriptive statistics and correlations

For sample description, Table 2 provides raw-score means, standard deviations and the correlation between tests. This might be important for further interpretations.

Dimensions of motor fitness

The two-level model (Figure 3) revealed an acceptable degree of overall model fit [χ^2 (17) = 315.252; Bollen-Stine p value = 0.005; RMSEA = 0.079 (90% confidence

Table 2. Means, standard deviations and correlations of motor performance ability items

	M	SD	erg	fpl	lgj	pup	jsw	sol	bbw	fbt
erg	1.99	0.49	1.00	0.24*	0.40*	0.34*	0.20*	–0.19*	0.17*	–0.07*
fpl	11.85	3.74	0.24*	1.00	0.55*	0.51*	0.53*	–0.40*	0.40*	0.08*
lgj	146.55	32.67	0.40*	0.55*	1.00	0.85*	0.69*	–0.47*	0.44*	0.09*
pup	0.30	0.07	0.34*	0.51*	0.85*	1.00	0.70*	–0.46*	0.41*	0.07*
jsw	27.40	9.34	0.20*	0.53*	0.69*	0.70*	1.00	–0.55*	0.49*	0.11*
sol	7.25	7.09	–0.19*	–0.40*	–0.47*	–0.46*	–0.55*	1.00	–0.62*	–0.13*
bbw	30.98	10.22	0.17*	0.40*	0.44*	0.41*	0.49*	–0.62*	1.00	0.15*
fbt	–0.27	7.85	–0.07*	0.08*	0.09*	0.07*	0.11*	–0.13*	0.15*	1.00

*$p < 0.01$. M = mean; SD = standard deviation; erg = bicycle ergometer test; fpl = force plate; lgj = long jump; pup = push-ups; jsw = jumping sideways; sol = standing on one leg; bbw = balancing backwards; fbt = forward bending of the trunk.

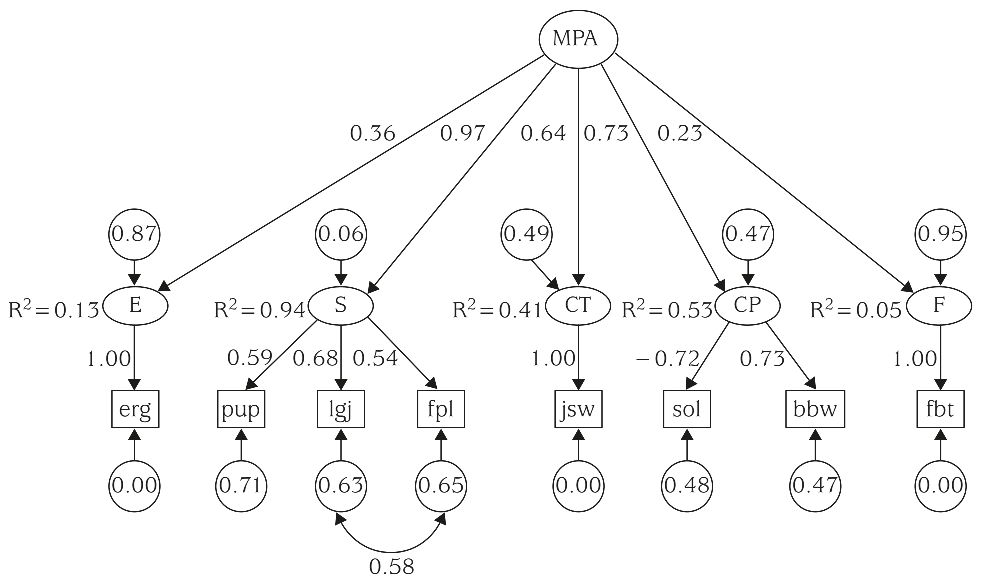

Fig. 3 Standardized solution. MPA = motor performance ability; E = endurance; S = strength; CT = coordination under time pressure; CP = coordination with precision requirement; F = flexibility; erg = bicycle endurance test; pup = push-ups; lgj = long jump; fpl = force plate; jsw = jumping sideways; sol = standing on one leg; bbw = balancing backwards; fbt = forward bending of the trunk.

interval, 0.071–0.086); SRMR = 0.047; CFI = 0.95]. The loadings on the manifest variables ranged from low to high (coordination under precision demands: a = 0.73 and a = –0.72; strength: a = 0.54 to a = 0.68; MPA: a = 0.23 to a = 0.97), but were all significant ($p < 0.001$). The correlated errors of force plate and long jump reached significance ($r = 0.58$; $p < 0.001$).

Strength, as a first-level factor, is nearly equally described by push-ups and force plate, and described somewhat more by long jump. Nearly equal loadings on the first-level factor of coordination under precision demands were obtained for standing on one leg and balancing backwards.

Thus, motor fitness as a higher-level factor is primarily described by strength and coordination under precision demands, followed by coordination under time pressure. Flexibility and endurance are comparatively less meaningful. MPA explained 94% of the strength variance. The explained variance of coordination under precision demands amounted to 53%, for coordination under time pressure, 41%, for endurance, 13%, and for flexibility, only 5%.

Discussion

The present study was an attempt to verify a theoretically and empirically based, two-level model describing MPA and its dimensions especially for children and adolescents. This, against the background of

(1) decreasing levels of physical fitness (Kretschmer & Wirszing 2007; Bös 2003), (2) their associations with health status (Opper et al. 2005), (3) the lack of knowledge of what MPA for children and adolescents comprises, and (4) as a follow-up to be able to compare results concerning MPA of children and adolescents even if measured with different test batteries.

MPA for children and adolescents is described here, referring to the theoretical model of Bös (1987), as a second-order factor based on the five first-order factors of endurance, strength, coordination under time pressure, coordination under precision demands and flexibility. These five dimensions are individually conceived of as bicycle ergometer test, high jump, standing long jump, push-ups, jumping sideways, standing on one leg, balancing backwards and forward bending of the trunk. The speed of strength is described by the two measures, high jump as an apparatus-supported test and standing long jump as a practice-oriented test. The results show that the postulated model fits. The fit of the model is comparable to other verifications of dimensionalities with different target groups or using different test batteries (Bös, Schlenker, Büsch et al. 2009; Nagasaki et al. 1995). MPA for children and adolescents can consequently be understood as an interrelationship of the assumed functional factors, whereby those with higher loadings (strength, coordination under precision demands and coordination under time pressure) are seen to play a more important role. Note in this context that coordination under time pressure, endurance and flexibility consist of only one test item. Especially, the loading of flexibility is very low. This confirms the assumption that flexibility is a rather independent dimension ("passive system of energy transfer"). Aside from that, the loading from MPA to endurance is also quite low. This shows that endurance seems to also be a specific component of MPA and it is not as highly intercorrelated with other components as, for example, strength. The low loadings of flexibility and endurance have also been found for older adults (Nagasaki et al. 1995). As expected, both speed of strength measures, as manifest variables, present a moderate correlation. Nevertheless, both tests can be described by strength as well as push-ups. Standing on one leg and balancing backwards are well described by coordination under precision demands. To summarize, the assumed tests can be described by the assumed dimensions which themselves can be described by the MPA of children and adolescents.

Thus, this model provides knowledge about the dimensions of MPA in children and adolescents. It therefore gives the opportunity for prospective international MPA or health studies, including MPA to utilize a theoretically based and empirically proofed model that provides an opportunity for comparing the results.

The presented MoMo test battery aspires to be easily applicable for use in practice (schools, sport clubs, etc.) and research studies. It has been especially developed for use in small rooms as it is often the condition in health surveys (e.g. KiGGS study). Studies have shown that the feasibility of the MoMo test battery is very good (Bös, Worth, Opper et al. 2009). Practitioners using motor test batteries often desire to be able to describe MPA with only one measure that means summing up the information of all motor dimensions. The results of the present study suggest that MPA cannot be exactly described by only one measure. It is not possible to use a sum score of a test battery if applying fitness tests in practice, since strength, coordination under precision demands and coordination under time pressure would be overestimated, whereas endurance and flexibility would be underestimated. In practice, if using fitness tests, one should better use fitness profiles on each dimension rather than a general sum score (Bös, Worth, Opper et al. 2009).

The analyses carried out have shown that the postulated dimensionality of MPA is valid for children and adolescents. This knowledge about the dimensionality of MPA for children and adolescents is very important for further research. During the past 2 years, an applicable and feasible test battery for nationwide use in physical education lessons in schools has been developed on the base of the presented MoMo test battery and the presented dimensionality model (Bös, Schlenker, Büsch et al. 2009). Also, a nationwide longitudinal survey about MPA of children and adolescents in Germany—the continuation of MoMo—is being carried out at the moment on the base of the presented dimensionality model. Nevertheless, further research is needed to strengthen the information already acquired. The validity of the differentiation for children with motor disorders, retarded motor development or handicaps should be evaluated, since these target groups are often diagnosed by motor tests. In this case, fine-motor abilities should be included in the test batteries.

Acknowledgments

The MoMo study was sponsored by the Federal Ministry for Families, Senior Citizens, Women and Adolescents (BMFSFJ) from the years 2002 to 2008.

References

Beauducel A, Wittmann WW (2005). Simulation study on fit indexes in CFA based on data with slightly distorted simple structure. *Structural Equation Modeling* 12:41–75.

Bös K (1987). *Handbuch Sportmotorischer Tests. [Handbook of Sport-motor Tests.]* Hogrefe, Göttingen.

Bös K (1992). Sport international—the relevance of fitness tests and fitness programs in European countries—results from a questionnaire with fitness experts. *Int J Phys Educ* 29:37–9.

Bös K (2001). *Handbuch Motorischer Tests. [Handbook of Motor Tests.]* Hogrefe, Göttingen.

Bös K (2003). Motorische Leistungsfähigkeit von Kindern und Jugendlichen [Motor performance ability of children and adolescents]. In: Schmidt W, Hartmann-Tews I, Brettschneider WD (Eds.), *Erster Deutscher Kinder und Jugendsportbericht. [First German Sport Report for Children and Adolescents.]* Hofmann, Schorndorf, pp. 85–108.

Bös K, Mechling H (1983). *Dimensionen Sportmotorischer Leistungen. [Dimensions of Sport-motor Performance.]* Hofmann, Schorndorf.

Bös K, Mechling H (1985). *International Physical Performance Test Profile for Boys and Girls From 9–17 Years (IPPTP 9–17).* International Council of Sport Science and Physical Education, Cologne.

Bös K, Tittlbach S (2002). Motorische Tests—für Schule und Verein—für jung und alt. [Motoricity tests—for schools and clubs—for the young and the old.] *Sportpraxis Sonderheft* 43:4–70.

Bös K, Schlenker L, Büsch D, Lämmle L, Müller H, Oberger J, Seidel I, Tittlbach S (2009). *Deutscher Motorik Test 6–18. [German Sport-motoric Test 6–18.]* Czwalina, Hamburg.

Bös K, Worth A, Heel J, Opper E, Romahn N, Tittlbach S, Wank V, Woll A (2004). *Testmanual des Motorik-Moduls im Rahmen des Kinder und Jugendgesundheitssurveys des Robert Koch-Instituts. [Test Manual of the Motoric Module as Part of the German Health Interview and Examination Survey for Children and Adolescents Performed by the Robert-Koch Institute.]* Bundesarbeitsgemeinschaft für Haltungs- und Bewegungsförderung, Wiesbaden.

Bös K, Worth A, Opper E, Oberger J, Romahn N, Wagner M, Jekauc D, Mess F, Woll A (2009). *Das Motorik-Modul: Motorische Leistungsfähigkeit und Körperlich-sportliche Aktivität von Kindern und Jugendlichen in Deutschland. [The Motoric-module: Motor Performance Ability and Physical Activity of Children and Adolescent in Germany.]* Nomos-Verlag, Baden-Baden.

Bührle M, Schmidtbleicher D (1981). Komponenten der Maximal und Schnellkraft. [Components of maximum and speed strength.] *Sportwissenschaft: The German Journal of Sports Science* 11:11–27.

Corbin CB (1991). A multidimensional hierarchical model of physical fitness: a basis for integration and collaboration. *Quest* 43:296–306.

Cratty BJ (1979). *Motorisches Lernen und Bewegungsverhalten. [Motor Learning and Movement Behavior.]* Limpert, Bad Homburg.

Fleishman EA (1954). Dimensional analysis of the psychomotor abilities. *J Exp Psychol* 48:437–54.

Fleishman EA, Quaintance ML (1984). *Taxonomies of Human Performance.* Academic Press, New York.

Fu FH, Nie J, Tong TK (2004). An overview of health fitness of Hong Kong children and adults in the past 20 years (1984–2004)—Part 2. *J Exerc Sci Fit* 2:64–78.

Graf C, Koch B, Falkowski G, Jouck S, Christ H, Staudenmaier K, Tokarski W, Gerber A, Predel HG, Dordel S (2008). School-based prevention: effects on obesity and physical performance after 4 years. *J Sports Sci* 26: 987–94.

Greene LS, Williams HG, Macera CA (1993). Identifying dimensions of physical (motor) functional capacity in healthy older adults. *J Aging Health* 5:163–78.

Hands B, Larkin D (2006). Physical fitness differences in children with and without motor learning difficulties. *Eur J Spec Needs Educ* 21:447–56.

Hirtz P (1977). Struktur und Entwicklung koordinativer Leistungsvoraussetzungen bei Schulkindern. [Structure and development of coordinative performance requirements in school children. Theory and practice of the physical culture.] *Theor Prax Korperkult* 26:381–7.

Hollmann W, Hettinger T (2000). *Sportmedizin [Sports Medicine]*. Schattauer, Stuttgart.

Hu LT, Bentler PM (1999). Cut off criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling* 6:1–55.

Kamtsiuris P, Lange M, Schaffrath Rosario A (2007). Der Kinder- und Jugendgesundheitssurvey (KiGGS): Stichprobendesign, Response und Nonresponse-Analyse. [The German Health interview and Examination Survey for Children and Adolescents (KiGGS): sample design, response and nonresponse analysis.] *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 50:547–56.

Kiphard EJ, Schilling F (1974). *Körperkoordinationstest für Kinder (KTK) [Physical Coordination Test for Children]*. Beltz-Verlag, Weinheim.

Kretschmer J, Wirszing D (2007). *Mole. Motorische Leistungsfähigkeit von Grundschulkindern in Hamburg. [Mole. Motor Performance Ability of Primary School Children in Hamburg.]* Moeve, Hamburg.

Kurth B (2007). Der Kinder- und Jugendgesundheitssurvey (KiGGS): Ein Überblick über Planung, Durchführung und Ergebnisse unter Berücksichtigung von Aspekten eines Qualitätsmanagement. [The German Health Interview and Examination Survey for Children and Adolescents (KiGGS): An overview of its planning, implementation and results taking into account aspects of quality management.] *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 50: 533–46.

Nagasaki H, Itoh H, Furuna T (1995). A physical fitness model of older adults. *Aging Clin Exp Res* 7:392–7.

Opper E, Worth A, Bös K (2005). Kindergesundheit – Kinderfitness. [Childhood health and fitness.] *Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz* [*German Federal Gazette for Health Research and Protection]* 8:854–62.

Powell A, Katzko M, Royce R (1978). A multifactor-systems theory of the structure and dynamics of motor functions. *J Mot Behav* 10:191–210.

Roth K (1982). *Strukturanalyse Koordinativer Fähigkeiten. [Structural Analysis of Coordinative Abilities.]* Limpert, Bad Homburg.

Schmidtbleicher D (1980). *Maximalkraft und Bewegungsschnelligkeit. [Power and Movement Speed.]* Limpert, Bad Homburg.

Suni J (2000). *Health-related Fitness Test Battery for Middle-aged Adults*. Jyväskylä University Printing House, Jyväskylä.

Weineck J (2007). *Optimales Training. Leistungsphysiologische Trainingslehre unter besonderer Berücksichtigung des Kindes und Jugendtrainings. [Optimal Training. Performance Physiology Oriented Exercise Testing and Prescription with Particular Consideration of Training for Children and Adolescents.]* Spitta, Balingen.